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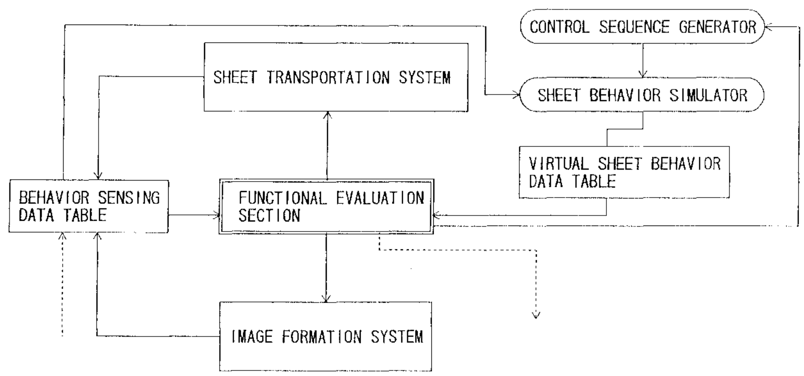
(54) Functional evaluation method and apparatus for maintenance automation of an image forming apparatus

(57) A functional evaluation method and apparatus for an image forming apparatus are provided which are capable of performing functional evaluation on a plurality of functional systems such as an image formation system and a sheet transportation system in the image forming apparatus in a totalized manner for fault repair. A functional system to be subjected to functional evaluation is represented by a physical parameter model, a functional modifier configuration utilizing an FBS diagram and a functional modifier, and a functional quantity for relating the physical parameter model and the functional modifier configuration. The function manifestation level of the functional system of interest is evaluated in a state where data indicative of the state of the functional system outputted from sensors are fitted to the parameter model. If the function manifestation level is low, it is judged that a fault occurs, and a parameter is retrieved from the parameter model for improvement of the function manifestation level. Therefore, the functional evaluation of a plurality of functional systems can be performed in a totalized manner.

F I G. 3



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to maintenance automation of an image forming apparatus and, more specifically, to maintenance automation of an image forming apparatus imparted with self-diagnostic and self-repair functions. Particularly, the present invention proposes a method and an apparatus for functional evaluation of an image forming apparatus, which are required for evaluating the functioning state of the apparatus for the maintenance automation.

Description of Related Art

In the field of image forming apparatuses such as a copying machine, the provision of a so-called self-repair function has been proposed. The self-repair function aims at "functional maintenance" which is achieved, for example, by the fault diagnosis of functions related to image formation and the repair of a faulty function. A prior-art apparatus having such a self-repair function is disclosed in Japanese Unexamined Patent Publication No. 4-130331 (1992) according to the prior application filed by the applicant of the present invention.

In the prior art, the characteristics of an image forming apparatus to be self-repaired are represented as cause and effect relations between a plurality of physical parameters. When a fault occurs, physical parameters to be manipulated are retrieved on the basis of qualitative inference, and the fault is repaired by manipulating the physical parameters.

In the qualitative inference, it is checked whether the functions to be maintained are active and, if any of the functions is inactive, parameters related to the recovery of the inactive function are retrieved.

In the prior art, however, the degree of the degradation of a function and the degree of the recovery of the function are left out of consideration. This is because it is difficult to quantify an abstract concept of "function".

To overcome this difficulty, Japanese Unexamined Patent Publication No. 5-165279 (1993) has proposed a method for representing a function of an object using FBS (function-behavior-state) diagrams. The characteristics including functions of an objective machine to be maintained can be represented by FBS diagrams.

Where the functional maintenance of the objective machine is to be performed by a computer on the basis of FBS diagrams representing the characteristics of the objective machine, however, available information is insufficient. To cope with this problem, a concept of "functional quantity" is introduced which enables the quantification of a function for representation thereof (detailed description can be found in Japanese Unexamined Patent Publication No. 7-104802 (1995)).

Further, a function representation method has been proposed in which a concept of "functional modifier" is introduced to represent a functional quantity in a more concrete manner, and a function expanding configuration for a copying machine has also been proposed (detailed description can be found in US Patent Application serial No. 08/403,423 and EP Patent Application Laid-Open Publication No. 0672959).

The aforesaid prior arts for an image forming apparatus both present epoch-making approaches to the maintenance of an image formation function which is a dominant function of the apparatus, and realize the functional maintenance automation.

In terms of the maintenance of the overall image forming apparatus, however, these arts are not satisfactory which deal only with the quality maintenance of formed images. It is therefore desirable to cover a wider range of objective functions for maintenance thereof.

In recent years, a need has arisen for sequentially feeding a multiplicity of sheets in an image forming apparatus such as a copying machine for the speeding up of the operation of the apparatus. The sequential feeding of the multiplicity of sheets essentially requires improvement of the performance and stability of a sheet transportation system of the apparatus.

Unfortunately, most of presently available sheet transportation systems or mechanisms can use only limited types of sheets made of specific materials, and can be used only in a specific operational environment because of their performance unstableness toward a change in the operational environment.

The sheet transportation system per se deteriorates with time due to the aging of components thereof to cause a sheet feeding failure (e.g., plural-sheet feeding, no-sheet feeding, and sheet jam). When such a failure occurs, a typical approach to the functional maintenance of the system is the cleaning of the system or the replacement of a faulty component.

The inventors of the present invention have conducted an intensive research and development on a highly advanced and feasible image forming apparatus which is capable of performing self-diagnosis and self-repair of its sheet transportation system in addition to the repair of its image formation function.

The research and development has been conducted on the following basis.

In an attempt to self-repair a sheet transportation system as well as an image formation system in a copying machine, a typical approach is to provide a functional evaluation section for image formation and a functional evaluation section for sheet transportation in the image formation system and in the sheet transportation system, respectively, as shown in Fig. 1.

A comparison between the evaluation of the image formation and the evaluation of the sheet transportation indicates that evaluation parameters to be used for the image formation evaluation have some relation with evaluation parameters to be used for the sheet transportation evaluation and, therefore, these evaluation processes cannot be independently performed. Where sheet transportation speeds are represented by a certain parameter, for example, a sheet transportation speed optimum for the sheet transportation is not necessarily equal to a sheet transportation speed optimum for the image formation. Accordingly, the evaluation processes independently performed in the image formation functional evaluation section and in the sheet transportation functional evaluation section with the use of the same parameter bring about different results.

It is therefore necessary to provide a central functional evaluation section for unifying functional evaluation sections respectively provided in a plurality of systems thereby to totalize evaluation results obtained in the respective functional evaluation sections.

The construction shown in Fig. 1 is not efficient because the central functional evaluation section should retain knowledge data which are mostly overlapped with those retained in the respective functional evaluation sections.

Where a functional evaluation process for an additional system in the copying machine, e.g., productivity evaluation or operability evaluation on a structural system thereof, is to be introduced, the relationship between the newly introduced evaluation process and the existing image formation evaluation or sheet feeding evaluation process should be re-described. Therefore, this approach results in a reduced versatility.

SUMMARY OF THE INVENTION

As a result of the research and development, there has been developed a functional evaluation method and apparatus which are capable of evaluating the overall function of an image forming apparatus for self-repair of its image formation system and sheet transportation system.

It is therefore an object of the present invention to provide a functional evaluation method and a functional evaluation apparatus having such features.

In accordance with the present invention, a frame for evaluating the overall function of a copying machine, i.e., a functional evaluation section for the copying machine, is provided which is adapted to evaluate the functions of an image formation system and a sheet transportation system thereof in a totalized manner. The respective systems are adapted to self-repair their functions on the basis of the evaluation result.

The provision of the functional evaluation section for the overall copying machine allows for functional evaluation of the copying machine without considering the results of the image formation functional evaluation and the sheet transportation functional evaluation obtained in the respective systems.

If it is desired to impart a self-repair function to an additional system in the copying machine, the plug-in of the additional system can readily be achieved by increasing the amount of knowledge data to be manipulated by the functional evaluation section.

In accordance with one aspect of the present invention, there is provided a functional evaluation method for evaluating an operational state of an image forming apparatus which includes a combination of a plurality of systems, such as a sheet transportation system and an image formation system, respectively having different functions, the method comprising the steps of: providing a functional evaluation section for evaluating an overall function of the image forming apparatus; and performing functional evaluation on systems selected from the plurality of systems of the image forming apparatus in a totalized manner by means of the functional evaluation section.

In accordance with another aspect of the present invention, the method further comprises the step of performing a repair operation on a system which is determined to be in an unsatisfactory function manifesting state on the basis of an evaluation result outputted from the functional evaluation section, for improvement of the function manifesting state thereof.

In accordance with further another aspect of the present invention, the method further comprises the steps of: providing a sheet behavior control sequence generation section, a sheet behavior simulation section and a virtual sheet behavior data table as software components in a computer in addition to hardware components of the sheet transportation system for the functional evaluation of the sheet transportation system; constructing a virtual sheet transportation system in the computer by means of the software components, and performing the functional evaluation on the real sheet transportation section on the basis of the virtual sheet transportation system; and employing a result of the functional evaluation for repair of the hardware components of the real sheet transportation system.

In accordance with still another aspect of the present invention, the step of performing the functional evaluation on the selected systems in a totalized manner comprises the steps of: specifying a functional system to be subjected to the functional evaluation in the image forming apparatus; representing the specified functional system as a parameter model from a physical configurational viewpoint; describing the specified functional system as a functional modifier configuration from a functional viewpoint by using a function-behavior-state diagram and a functional modifier; relating the parameter model with the functional modifier configuration by a functional quantity; extracting data indicative of a state of the specified functional system to be evaluated therefrom; determining a function manifestation level on the basis of the functional modifier configuration and the functional quantity by fitting the extracted data in the parameter model; determining on the basis of the functional quantity a shift direction in which a parameter value is to be shifted for maximization of the function manifestation level if the function manifestation level does not reach a predetermined level; performing a qualitative simulation in the parameter model, and retrieving a parameter which enables the parameter value to be shifted in the determined shift direction and an actuator to be operated for manipulating the parameter; and evaluating a function manifestation level resulting from operation of the retrieved actuator.

In accordance with further another aspect of the present invention, the step of representing the specified functional system as a parameter model from a physical configurational viewpoint, when a plurality of functional systems are respectively represented as parameter models, comprises a step of checking whether or not the parameter models of the plurality of functional systems include the same parameter and, if the same parameter is included, relating the parameter models with each other by the parameter.

In accordance with still another aspect of the present invention, the step of describing the specified functional system as a functional modifier configuration by using a function-behavior-state diagram and a functional modifier, when a plurality of functional systems are respectively described as functional modifier configurations, comprises the step of checking whether or not the functional modifier configurations of the functional systems include the same functional modifier and, if the same functional modifier is included, relating the functional modifier configurations with each other by the functional modifier.

In accordance with further another aspect of the present invention, there is provided a functional evaluation apparatus for an image forming apparatus including a combination of a plurality of functional systems, such as a sheet feeding system, an image forming system, and the like, respectively having different functions, the apparatus comprising: parameter model storage means storing therein a parameter model representing a physical configuration of a functional system to be evaluated; functional modifier configuration storage means storing therein a functional modifier configuration representing a functional configuration of the functional system to be evaluated with the use of a function-behavior-state diagram and a functional modifier; functional quantity storage means storing therein a functional quantity for relating the parameter model with the functional modifier configuration; a plurality of sensor means disposed in the respective functional systems for determining a state of the functional system to be evaluated; and evaluation means for evaluating a function manifestation level on the basis of the functional modifier configuration and the functional quantity in a state where output data of the respective sensors are fitted in the parameter model.

In accordance with still another aspect of the present invention, the apparatus further comprises actuator specifying means for retrieving, if there is any functional system having a function manifestation level not greater than a predetermined level, a parameter for increasing the function manifestation level of the functional system from the parameter model on the basis of an evaluation result outputted from the evaluation means, and determining and outputting an actuator for manipulating the retrieved parameter.

In accordance with further another aspect of the present invention, the apparatus further comprises fault repair evaluation means for determining whether or not the value of the parameter manipulated by the specified actuator is shifted in the image forming apparatus, reevaluating a function manifestation level after the shifting of the parameter value, and determining on the basis of a reevaluation result whether or not a fault repair is succeeded.

In accordance with still another aspect of the present invention, the apparatus further comprises a data table for storing therein the output data of the plurality of sensor means, wherein the evaluation means for evaluating the function manifestation level reads out data from the data table for the evaluation.

With the foregoing arrangements, where a plurality of functional systems are to be evaluated in the image forming apparatus, the functional systems can each be represented by a parameter model, a functional modifier configuration and a functional quantity. Therefore, if a fault occurs in any of the functional systems to be evaluated, an actuator necessary for the repair of the fault can readily be retrieved and, at the same time, how the repair of the fault influences the other functional systems can readily be checked. Thus, the functional evaluation can be performed on the plurality of functional systems in a totalized manner.

The invention is described further hereinafter, by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is a block diagram illustrating a construction for unifying functional evaluation sections in a copying machine which was examined in a research and development process to attain the present invention;

Fig. 2 is a block diagram illustrating the construction of a functional evaluation section for a copying machine in accordance with the present invention;

Fig. 3 is a diagram illustrating the outline of the overall construction of a copying machine according to one embodiment of the present invention;

Fig. 4 is a block diagram illustrating the overall construction of a sheet transportation device;

Fig. 5 is a block diagram illustrating an exemplary construction of the functional evaluation section;

Fig. 6 is a diagram illustrating an exemplary parameter model for evaluation of image formation;

Fig. 7 is a diagram illustrating an exemplary parameter model for evaluation of sheet transportation;

Fig. 8 is a flow chart illustrating the outline of an algorithm for a functional evaluation and repair process;

Figs. 9A to 9C are diagrams illustrating a model and functional states to be applied to the functional evaluation section of the copying machine; and

Figs. 10A to 10C are diagrams for explaining shift directions in which the values of parameters for functional evaluation are to be shifted to ensure the maximum function manifestation level.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

1. Outline of Copying Machine According to the Present Invention

A functional evaluation section to be hereinafter described is adapted to perform functional evaluation of an overall copying machine as described with reference to Fig. 2. It is noted that the functional evaluation section is completely different from the central functional evaluation section of Fig. 1 which is adapted to unify the plurality of functional evaluation sections.

Fig. 3 illustrates the outline of the overall construction of a copying machine according to one embodiment of the present invention.

Referring to Fig. 3, the copying machine has an image formation system and a sheet transportation system. These systems are each provided with a necessary sensor, and data outputted from the sensor are applied to a copying machine behavior sensing data table. More specifically, the data table stores data indicative of the latest state of the copying machine, and the data are constantly updated with the operation of the copying machine.

The functional evaluation section of the copying machine always evaluates the functions of the image formation system and the sheet transportation system on the basis of the data stored in the data table. If the evaluation results indicate that the function manifesting state of the image formation section is unsatisfactory, for example, a repair signal is applied to the image formation system which, in turn, repairs itself.

Similarly, if the function manifesting state of the sheet transportation system is unsatisfactory, a repair signal is applied to the sheet transportation system which, in turn, repairs itself.

When the self-repair operation is completed in the image formation system and the sheet transportation system, data indicative of the states of the respective systems after the completion of the self-repair are written in the data table.

The functional evaluation of an additional system is also performed by the functional evaluation section of the copying machine.

In this embodiment, there are provided a sheet behavior control sequence generation section, a sheet behavior simulation section and a virtual sheet behavior data table for the sheet transportation system. The fault repair of the sheet transportation system is not achieved by a conventional method in which the real sheet transportation system is operated and, if the degradation of its function is detected, a parameter is manipulated to recover the function, then the sheet transportation system is operated, and the function manifesting state is evaluated. Instead, the fault repair of the sheet transportation system is achieved by constructing a virtual sheet transportation system in a computer and evaluating the virtual sheet transportation system. This is realized by the provision of the sheet behavior control sequence generation section, the sheet behavior simulation section and the virtual sheet behavior data table. More specifically, the repair of the sheet transportation system is not based on the trial and error method but on the simulation of a virtual sheet behavior. A more specific explanation will be given thereto later.

2. Construction of Sheet Transportation Device

Fig. 4 is a block diagram illustrating the overall construction of the sheet transportation device. The functional evaluation section of the copying machine and the copying machine behavior sensing data table described with reference to Fig. 3 are also shown in Fig. 4 for convenience of explanation.

Referring to Fig. 4, the sheet transportation device includes a plurality of units 8 and a system body 10.

The plurality of units 8 include a sheet feeding unit for performing a sheet feeding operation, a sheet transporting unit for performing a sheet transportation operation, a sheet outputting unit for outputting a transported sheet to a predetermined place, and the like. There may be provided one or more sheet feeding units, sheet transportation units, sheet outputting units, and the like.

The sheet transportation system is not constructed as an integral hardware component adapted for sheet feeding, sheet transportation and sheet outputting, but is divided into a plurality of smaller units which constitute the sheet transportation system on a hardware basis. The units each have a construction adapted for an autonomous operation, which will be described later. Thus, the units are each capable of performing a self-repairing operation in an autonomous manner.

Though not shown, the units 8 each include rollers for applying a transportation force to a sheet, a motor for rotating the rollers, a clutch for selectively applying the driving force of the motor to the rollers, and the like.

The units 8 each include a plurality of sensors 9 for sensing the rotational state of the rollers, a biasing force applied to a sheet by the rollers, the rotational speed and direction of the motor, and the like. It is noted that the sensors 9 and the units are separately shown in Fig. 4 for convenience of illustration.

The system body 10 includes a control data management section 20, a sequence formulation section 23, a knowledge base 24, a state derivation section 25, a simulation section 26 and a dividing section 27.

A data table 21 and an evaluation section 22 included in the system body 10 in Fig. 4 are not in a dedicated use for the sheet transportation system, but correspond to the copying machine behavior sensing data table and the copying machine functional evaluation section, respectively, shown in Fig. 3. It is noted that the data table 21 and the evaluation section 22 are provided in the system body 10 in Fig. 4 merely for convenience of explanation.

More specifically, the data table 21 retains data for the image formation system as well as data for the sheet transportation system. The evaluation section 22 performs evaluation not only on the sheet transportation system but also on the image formation system.

For convenience of the explanation of the sheet transportation device, the data table 21 and the evaluation section 22 are provided in the system body 10, since it is readily understood what data the data table 21 stores for the sheet transportation system and how the evaluation section 22 performs the evaluation.

The control data management section 20 writes information data concerning the respective units 8 into the data table 21 in a predetermined updating cycle on the basis of signals outputted from the sensors 9 provided in the units 8. Thus, the data table 21 retains the current states (latest states) of the respective units 8 written therein.

The evaluation section 22 performs diagnostics on the current states of the respective units 8 on the basis of the information on the units 8 written in the data table 21. More specifically, the evaluation section 22 judges, for example, whether or not any of the units 8 is broken, whether or not the function of any of the units 8 is deteriorated, whether or not there is a possibility to cause a sheet jam, whether or not a sheet jam has occurred, or the like.

If the judgment results indicate that there is a possibility to cause a fault or that a fault has occurred (NO GOOD), the evaluation section 22 requests the sequence formulation section 23 to formulate a control sequence for repairing the fault. The control sequence formulated by the sequence formulation section 23 is simulated by the simulation section 26, and the simulation results are evaluated by the evaluation section 22. If the control sequence provides an evaluation result of "GOOD", the control sequence is divided into lower-level control sequences for the respective units 8 by the dividing section 27, and the resulting lower-level control sequences are respectively applied to the units 8.

Briefly, the sheet transportation device always monitors the overall state of the sheet transportation system and, if there occurs a state likely to cause a reduction in the sheet feeding speed or a jam, an improved control sequence is newly generated for maintenance of the overall function of the system, and the improved control sequence is applied to the respective units 8.

In response to a request to formulate a control sequence from the evaluation section 22, the sequence formulation section 23 performs a control sequence formulation operation. At this time, the sequence formulation section 23 refers to the knowledge information written in the knowledge base 24 in the system body 10.

The knowledge base 24 retains virtual models required for fault repairing operations written therein. More specifically, a sheet path model, a unit model, a sheet model, a transportation path model, a sensor model are written in the knowledge base 24. Among those, the sheet path model, the sheet model, the transportation path model and the sensor model are preliminarily defined.

The unit model is knowledge information corresponding to a difference between a state of a unit 8 expected by the system body 10 and an actual state of the unit 8 (e.g., deterioration of a component (transportation rollers, for example) in the unit 8). The unit model is updated on the basis of data read out of the data table 21 by the state derivation section 25. In other words, the unit model is information indicative of a time-related change in the behavior of the unit 8.

More specifically, the state derivation section 25 receives information on an ideal behavior of a control sequence presently executed by the unit 8 from the simulation section 26. The state derivation section 25 determines a difference between the actual behavior information on the unit 8 written in the data table 21 and the ideal behavior information, and writes information indicative of the difference as a unit model into the knowledge base 24.

The sequence formulation section 23 formulates a control sequence by using the knowledge information including the unit model. Thus, the current state of the unit 8 can be taken into consideration for the formulation of the control sequence.

The control sequence formulated by the sequence formulation section 23 is applied to the simulation section 26. The simulation section 26 simulates a sheet transportation operation in a virtual manner on the basis of the control sequence applied from the sequence formulation section. More specifically, the simulation section 26 specifies a transportation path and a sheet in a virtual manner on the basis of the sheet path model and the sheet model written in the knowledge base 24, and transports a virtual sheet along a virtual transportation path on the basis of the applied control sequence. At this time, the behavior of the virtual sheet is recognized by the simulation section 26. Further, the simulation section 26 obtains quantitative information such as a sheet transportation speed and the like at the unit 8, and reflects the quantitative information to the formulation of the control sequence. Thus, the formulation of the control sequence is completed.

The result of the sheet transportation simulation performed in the simulation section 26 is applied to the evaluation section 22. The evaluation section 22 determines on the basis of the simulation result applied from the simulation section 26 whether or not the control sequence formulated by the sequence formulation section

23 is valid.

If the evaluation result indicates that it is impossible to properly perform the sheet transporting operation on the basis of the formulated control sequence and to repair the fault (NO GOOD), the evaluation section 22 requests the sequence formulation section 23 again to formulate an alternative control sequence. If it is judged that the sheet transporting operation can properly be performed on the basis of the formulated control sequence for the fault repair (GOOD), the control sequence is applied to the dividing section 27.

The dividing section 27 divides the applied control sequence on a task basis, and the resulting lower-level control sequences are respectively applied to the units 8. More specifically, since the control sequence is a time-series program, it is predicted that plural units 8 are involved in the execution of the control sequence. Therefore, the lower-level control sequences are properly allocated to the units 8 responsible for the execution of the control sequence.

During the control sequence formulation process in the system body 10, the validity of the control sequence is evaluated by performing the simulation in the virtual sheet transportation system generated in the computer (system body 10), as described above. Therefore, fault prevention and fault repair can be achieved without interrupting the operations of the plurality of units 8 in the real sheet transportation system.

The units 8 each have a control section 13. The control section 13 includes a translation section 23 and a controllable self-repair section 29. The controllable self-repair section 29 includes a sequence execution section 30 and an autonomous operation section 31.

A lower-level control sequence applied from the dividing section 27 is translated into a unit-executable quantitative sequence by the translation section 28, and the sequence execution section 30 executes the quantitative sequence.

While the control sequence applied from the system body 10 is executed, the autonomous operation section 31 autonomously performs a fault repairing operation when a sheet feeding failure such as plural-sheet feeding or no-sheet feeding occurs.

3. Construction of Functional Evaluation Section

Fig. 5 is a block diagram illustrating an exemplary construction of the functional evaluation section.

The functional evaluation is achieved by function balancing. The characteristics of a system (objective system) to be subjected to the functional evaluation are represented by functional modeling, physical configuration modeling and functional quantities linking the functional modeling to the physical configuration modeling, as described in "Related Art".

More specifically, the functional modeling of the objective system is achieved by defining a functional modifier configuration with the use of FBS diagrams and functional modifiers. The functional modifier configuration allows for computation on the level of the functional quantity by weighting the functional modifiers.

The physical configuration modeling uses a parameter model. The functional modifier configuration is linked to the parameter model by the functional quantities.

The functional evaluation section in the copying machine shown in Fig. 5 stores therein the configuration of the copying machine represented by the functional modifier configuration, the functional quantities and the parameter model.

The functional evaluation section fits the data obtained from the sheet transportation system into the parameter model, and then compares the parameter model with the functional modifier configuration linked by the functional quantities to determine a parameter to be manipulated and the manipulation amount of the parameter. Substantially the same process is performed on the image formation system.

4. Exemplary Parameter Models

Fig. 6 illustrates an exemplary parameter model for the evaluation of the image formation. Fig. 7 illustrates an exemplary parameter model for the evaluation of the sheet transportation. Here, syllables A1 to A11 and B1 to B17 shown in Fig. 6 respectively represent meanings as follows:

A1 : CHARGE WIRE HIGH VOLTAGE TRANSFORMER
A2 : DRUM ROTATION SPEED
A3 : HALOGEN LAMP HIGH VOLTAGE TRANSFORMER
A4 : DRUM ROTATION SPEED
A5 : BIAS HIGH VOLTAGE TRANSFORMER
A6 : TRANSFER CHARGE WIRE HIGH VOLTAGE TRANSFORMER
A7 : SHEET SPEED DURING TRANSFER OPERATION
A8 : SHEET FLEXURE RADIUS DURING TRANSFER OPERATION
A9 : CONTACT ANGLE OF SHEET WITH RESPECT TO DRUM
A10: CONTACT PRESSURE OF SHEET AGAINST DRUM
A11: DRUM POSITIONING
B1 : Idrum
B2 : Imcwire
B3 : Vmcwire
B4 : MCWireVout
B5 : MCWireVcont
B6 : Imcshield
B7 : Rmcshield
B8 : HLVout
B9 : HLVcont
B10: BiaVout

B11: BiaVcont
B12: Iwire
B13: Vtcwire
B14: TCWireVout
B15: TCWireVcont
B16: Itcshield
B17: Rtcshield

As shown in the figures, the parameter model for the image formation evaluation and the parameter model for the sheet transportation evaluation include a common parameter such as sheet speed V_p.

Respective parameters included in the parameter models in Figs. 6 and 7 will be explained below.

(1) Parameters in Parameter Model for Image Formation Evaluation

Drum Charging Portion

$$Vn = Idrum \cdot Ddrum / (\varepsilon \cdot \varepsilon 0 \cdot v)$$

Vn: Surface potential of drum after main charging
Idrum: Corona current flowing into drum
Imcwire: Corona current flowing out of MC wire
Vmcwire: Voltage applied to MC wire
MCWireVout: MC wire output voltage from high voltage transformer
MCWireVcont: MC wire control voltage applied to high voltage transformer
Imcshielf: Corona current flowing into shield case
Rmcshield: Resistivity of shield case
ε: Dielectric constant of photoreceptor layer on drum
ε0: Dielectric constant in vacuo
v: Rotation speed of drum (process speed)
Ddrum: Thickness of photoreceptor layer on drum

Light Exposure Portion

$$ENi = ENb - D$$

ENi: Logarithm of light energy reflected on image portion
ENb: Logarithm of light energy reflected on background portion
D: Optical density of document original
X: Quantity of light projected on document
HL: Quantity of output light of halogen lamp
Rl: Quantity of light projected on reflector
HLq: Flux of light emitted from halogen lamp
HLt: Duration of light emission from halogen lamp
HLV: Voltage applied to halogen lamp
HLVout: Halogen lamp output voltage from high voltage transformer
HLVcont: Halogen lamp control voltage applied to high voltage transformer

Photoreceptor Portion

$$Vs = Vn - Va$$

Vs: Surface potential of drum after light exposure
Va: Potential reduced by light exposure
β: Sensitivity of drum

Transfer Portion

$$Absorp = Eap - Map$$

Absorp: Attractive force between sheet and photoreceptor
Eap: Electrostatic attractive force between sheet and photoreceptor
Vpa: Surface potential of sheet
Rp: Electric resistance of sheet
vp: Sheet speed (during transferring operation)
Ipa: Corona current flowing into sheet
Itcwire: Corona current flowing out of TC wire
Vtcwire: Voltage applied to TC wire
TCWireVout: TC wire output voltage from high voltage transformer
TCWireVcont: TC wire control voltage applied to high voltage transformer
Itcshield: Corona current flowing into shield case
Rtcshield: Resistivity of shield case
Map: Mechanical separation force between sheet and drum
Wpa: Width of sheet
Fpa: Flexibility of sheet
Rdrum: Curvature radius of drum
Rpa: Flexure radius of sheet (during transferring operation)
Gpa: Weight of sheet
Lt: Length of separated portion of sheet
Anpa: Contact angle of sheet with respect to drum
D-Pp: Contact pressure of sheet against drum
Dp: Drum positioning (positional relation between sheet and drum)
g: Gravity

Output Portion

$$Os = Absorp \cdot Ds$$

Os: Toner density on sheet

Development portion

$$Ds = \gamma O (Vs - Vb)$$

Ds: Toner density on photoreceptor drum
γO: Variable dependent on toner, developer and photoreceptor
Vb: Surface potential of development roller
TNq: Charge of toner
TNr: Particle diameter of toner
εO: Dielectric constant in vacuo
Cr: Coverage ratio
TNs: Toner supply rate
Dco: Characteristics of drum (dielectric constant, thickness of photoreceptor layer)
BiaVout: Bias output voltage from high voltage transformer
BiaVcont: Bias control voltage applied to high voltage transformer

(2) Parameters in Parameter Model for Sheet Transfer Evaluation

U-Uue: Number of undulations of sheet present between unit N and unit N+1
U-Ube: Length of portion of sheet present between unit N and unit N+1
U-Uv: Difference in sheet transportation speed between unit N and unit N+1
UnVp: Sheet speed at unit N
Un+1Vp: Sheet speed at unit N+1
U-Utime: Time period during which sheet is present at unit N and unit N+1
U-Usp: Space between unit N and unit N+1
U-Uint: Interval between unit N and unit N+1
BridHi: Height of bridge between unit N and unit N+1

5. Algorithm for Functional Evaluation and Repair Process

Fig. 8 is a flow chart illustrating the outline of an algorithm for a functional evaluation and repair process.

With reference to Fig. 8, operations to be performed at respective stages of the algorithm for the functional evaluation and repair process will be described.

Step S1: Judgment on Fault

The amount of the overall function of the copying machine (AOF) is calculated, and it is determined whether or not the AOF is greater than a threshold value serving as a criterion for judging the manifestation of a predetermined function. If the AOF is smaller than the threshold value, it is judged that a fault occurs.

Step S2: Determination of Shift Direction of Physical Parameter to be Monitored

A physical parameter to be shifted and a shift direction of the physical parameter are determined for improvement of the function manifesting state.

Step S3: Retrieval of Physical Parameter to be Manipulated

On the basis of a parameter model, a physical parameter to be manipulated is retrieved by a qualitative simulation.

If there is no such physical parameter, the process returns to Step S2 to determine another physical parameter and the shift direction of the physical parameter.

Step S4: Manipulation of Physical Parameter to be Manipulated

If the parameter is successfully retrieved in Step S3, the parameter is manipulated.

Step S5: Fault Judgment

It is determined how the AOF is changed by changing the manipulation amount of the parameter in Step S4. More specifically, the AOF is compared with the threshold value.

If the AOF is greater than the threshold value, the function manifesting state is improved so that the repair is successful.

Step S6: Retrieval of Manipulatable Physical Parameter

If the result of the fault judgment in Step S5 indicates that the AOF is smaller than the threshold value, the function manifesting state is unsatisfactory so that the machine is still in a faulty state. Therefore, another manipulatable physical parameter is retrieved. If there exists such a physical parameter, the process sequence from Step S2 is repeated.

If there is no such physical parameter, the repair fails.

The repairing operation to be performed by manipulating a physical parameter is herein referred to as "controllable self-repair".

6. Exemplary Functional Evaluation and Repair

The functional evaluation operation and the repair operation will be explained in greater detail.

For easy understanding, like steps will be denoted by like step numbers employed in the above explanation of the algorithm.

Figs. 9A to 9C illustrate exemplary relationships between functions and parameters for the functional evaluation (functional quantities), a functional modifier configuration, and a parameter model, respectively.

Assuming that the models and the state of the objective functional system to be applied to the functional evaluation section (see Fig. 3) in the copying machine are represented by Figs. 9A to 9C, the copying machine of Fig. 3 performs the functional evaluation operation and the repair operation in the following manner.

Step S1

Physical parameters (X, Y) in the parameter model of Fig. 9C are monitored, and the functional quantities (AOF_A, AOF_B, AOF_C) of the functions A, B, C in the functional modifier configuration of Fig. 9B are obtained. Here, "AOF" is the amount of the overall function as described above.

As a result, the AOF is calculated as follows:

$$AOF= (0.6 \times 0.7 \times AOF\_A) + (0.6 \times 0.3 \times AOF\_B) + (0.4 \times AOF\_C)$$

Therefore, it is judged that the AOF is lower than the threshold value.

Step S2

The shift direction of the value of each of the functional evaluation parameters for providing the maximum possible functional quantities of the respective functions is determined by using the functional quantities and the functional modifier configuration so that an E_function can exhibit the maximum functional quantity to attain an ideal repaired state. This is achieved on the basis of Fig. 9A.

As a result, the parameter X is to be increased for improvement of the functions A and B and the parameter Y is to be decreased for improvement of the function C as shown in Figs. 10A to 10C.

Since the repair operation is performed on a target of the ideal repaired state, the shift direction of each of the functional evaluation parameters is defined by a shift from a current point to a target point shown in Figs. 10A to 10C.

Step S3

An actuator to be manipulated to simultaneously shift the respective parameter values in the directions determined in Step S2 is retrieved from the parameter model shown in Fig. 9C. More specifically, a qualitative simulation is performed by using the parameter model.

Step S4

Thus, the actuator to be manipulated is retrieved. The actuator, if manipulatable, is manipulated.

If the actuator cannot be retrieved or if the actuator can be retrieved but is not manipulatable because of its manipulation limit, the aforesaid qualitative simulation is repeated.

Step S5

After the actuator is manipulated, the validity of the actuator manipulation is checked by comparing the functional quantity of the E_Function before the actuator manipulation with the functional quantity of the E_Function after the actuator manipulation.

If the function manifestation level of the E_Function is raised so that the AOF is not lower than the threshold value, it is judged that the repair operation is successful.

Step S6

If the function manifestation level is lowered after the manipulation of the actuator, it is judged whether or not there is another parameter (actuator) manipulatable for increasing the functional quantities of the E_Function before and after the actuator manipulation.

If there exists such a manipulatable parameter, the aforesaid qualitative simulation is performed again.

If there is no such parameter, the AOF remains lower than the threshold value so that the repair operation fails.

7. Conclusion

As described above, the image formation evaluation and the sheet transportation evaluation are performed as part of the functional evaluation of the overall copying machine by means of the functional evaluation section in the copying machine without considering the correlativity between the image formation evaluation and the sheet transportation evaluation.

8. Miscellaneous

Although the embodiment of the present invention has been described by employing a copying machine as the image forming apparatus, the invention is also applicable to other image forming apparatuses such as a printer and a facsimile machine.

In accordance with the present invention, an image forming apparatus including a plurality of systems to be controlled comprises a functional evaluation section which is used in common for the plurality of systems, so that the overall function of the apparatus can be evaluated by the functional evaluation section without considering evaluation results on the respective systems. This makes it possible to evaluate the functions of the plurality of systems in a totalized manner to realize maintenance automation of the plurality of systems. In addition, a wider range of maintenance objects can be covered.

More specifically, the present invention provides an image forming apparatus which realizes maintenance automation, for example, of its sheet transportation system and image formation system.

Further, the present invention provides a functional evaluation device which can readily cover additional systems for maintenance.

Claims

1. A functional evaluation method for evaluating an operational state of an image forming apparatus which includes a combination of a plurality of systems, such as a sheet transportation system and an image formation system, respectively having different functions, the method comprising the steps of:

   providing a functional evaluation section for evaluating an overall function of the image forming apparatus; and
   performing functional evaluation on systems selected from the plurality of systems of the image forming apparatus in a totalized manner by means of the functional evaluation section.

2. A functional evaluation method as set forth in claim 1, further comprising the step of:
   performing a repair operation on a system which is determined to be in an unsatisfactory function manifesting state on the basis of an evaluation result outputted from the functional evaluation section, for improvement of the function manifesting state thereof.

3. A function evaluation method as set forth in claim 2, further comprising the steps of:

   providing a sheet behavior control sequence generation section, a sheet behavior simulation section and a virtual sheet behavior data table as software components in a computer in addition to hardware components of the sheet transportation system for the functional evaluation of the sheet transportation system;
   constructing a virtual sheet transportation system in the computer by means of the software components, and performing the functional evaluation on the real sheet transportation section on the basis of the virtual sheet transportation system; and
   employing a result of the functional evaluation for repair of the hardware components of the real sheet transportation system.

4. A functional evaluation method as set forth in claim 1 or 2, wherein the step of performing the functional evaluation on the selected systems in a totalized manner comprises the steps of:

   specifying a functional system to be subjected to the functional evaluation in the image forming apparatus;
   representing the specified functional system as a parameter model from a physical configurational viewpoint;
   describing the specified functional system as a functional modifier configuration from a functional viewpoint by using a function-behavior-state diagram and a functional modifier;
   relating the parameter model with the functional modifier configuration by a functional quantity;
   extracting data indicative of a state of the specified functional system therefrom;
   determining a function manifestation level on the basis of the functional modifier configuration and the functional quantity by fitting the extracted data in the parameter model;
   determining on the basis of the functional quantity a shift direction in which a parameter value is to be shifted for maximization of the function manifestation level if the function manifestation level does not reach a predetermined level;
   performing a qualitative simulation in the parameter model, and retrieving a parameter which enables the parameter value to be shifted in the determined shift direction and an actuator to be operated for manipulating the parameter; and
   evaluating a function manifestation level resulting from operation of the retrieved actuator.

5. A functional evaluation method as set forth in claim 4, wherein the step of representing the specified functional system as a parameter model from a physical configurational viewpoint, when a plurality of functional systems are respectively represented as parameter models, comprises the step of:
   checking whether or not the parameter models of the plurality of functional systems include the same parameter and, if the same parameter is included, relating the parameter models with each other by the parameter.

6. A functional evaluation method as set forth in claim 5, wherein the step of describing the specified functional system as a functional modifier configuration by using a function-behavior-state diagram and a functional modifier, when a plurality of functional systems are respectively described as functional modifier configurations, comprises the step of:
   checking whether or not the functional modifier configurations of the functional systems include the same functional modifier and, if the same functional modifier is included, relating the functional modifier configurations with each other by the functional modifier.

7. A functional evaluation apparatus for an image forming apparatus including a combination of a plurality of functional systems, such as a sheet feeding system and an image forming system, respectively having different functions, the apparatus comprising:

parameter model storage means storing therein a parameter model representing a physical configuration of a functional system to be evaluated;

functional modifier configuration storage means storing therein a functional modifier configuration representing a functional configuration of the functional system to be evaluated with the use of a function-behavior-state diagram and a functional modifier;

functional quantity storage means storing therein a functional quantity for relating the parameter model with the functional modifier configuration;

a plurality of sensor means disposed in the respective functional systems for determining a state of the functional system to be evaluated; and

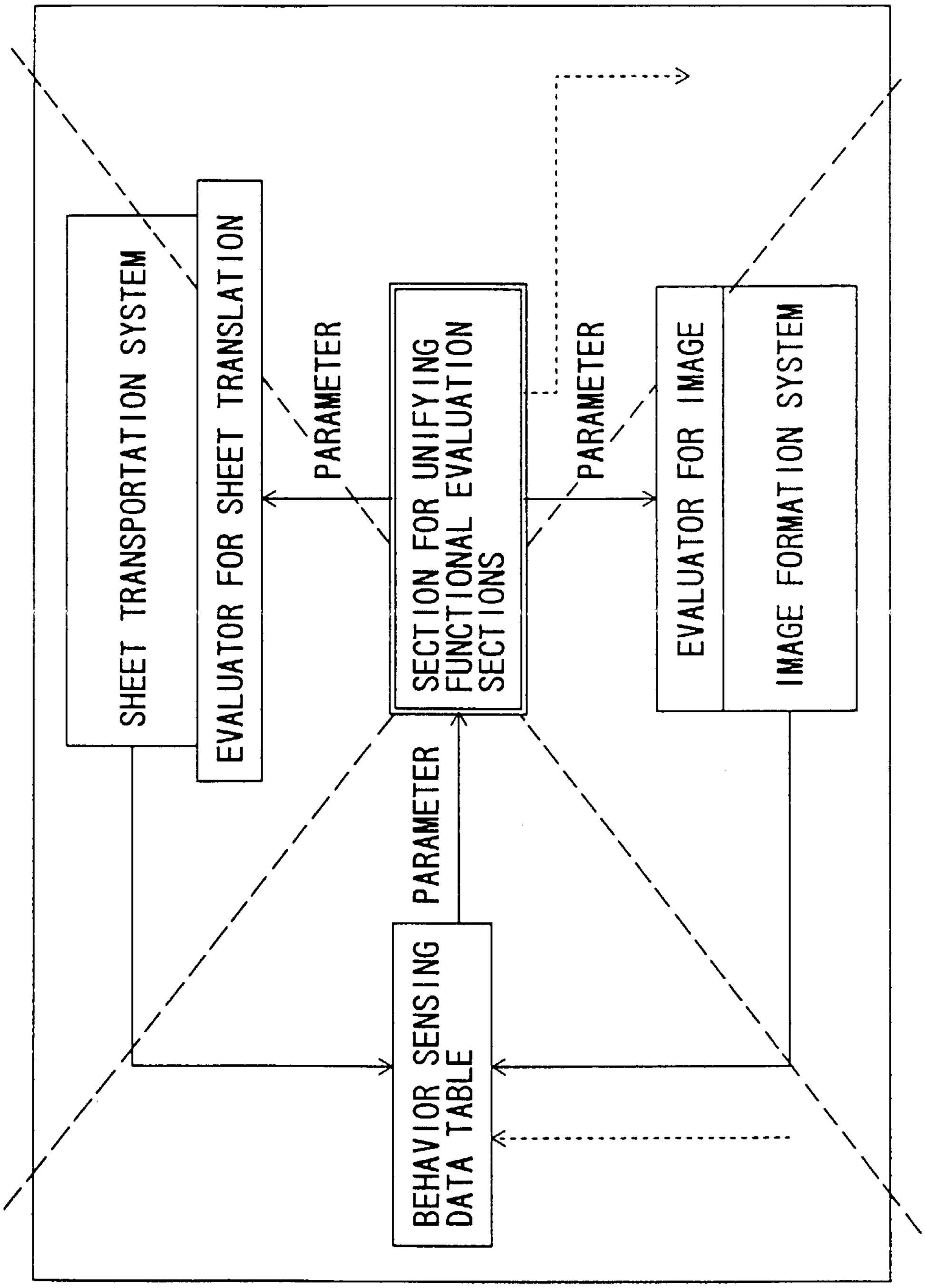
evaluation means for evaluating a function manifestation level on the basis of the functional modifier configuration and the functional quantity in a state where output data of the respective sensors are fitted in the parameter model.

8. A functional evaluation apparatus as set forth in claim 7, further comprising actuator specifying means for retrieving, if there is any functional system having a function manifestation level not greater than a predetermined level, a parameter for increasing the function manifestation level of the functional system from the parameter model on the basis of an evaluation result outputted from the evaluation means, and determining and outputting an actuator for manipulating the retrieved parameter.

9. A functional evaluation apparatus as set forth in claim 8, further comprising fault repair evaluation means for determining whether or not the value of the parameter manipulated by the specified actuator is shifted in the image forming apparatus, reevaluating a function manifestation level after the shifting-of the parameter value, and determining on the basis of a reevaluation result whether or not a fault repair is completed.

10. A function evaluation apparatus as set forth in claim 9, further comprising a data table for storing therein the output data of the plurality of sensor means, wherein the evaluation means for evaluating the function manifestation level reads out data from the data table for evaluation.

FIG. 1
PRIOR ART



F I G. 2

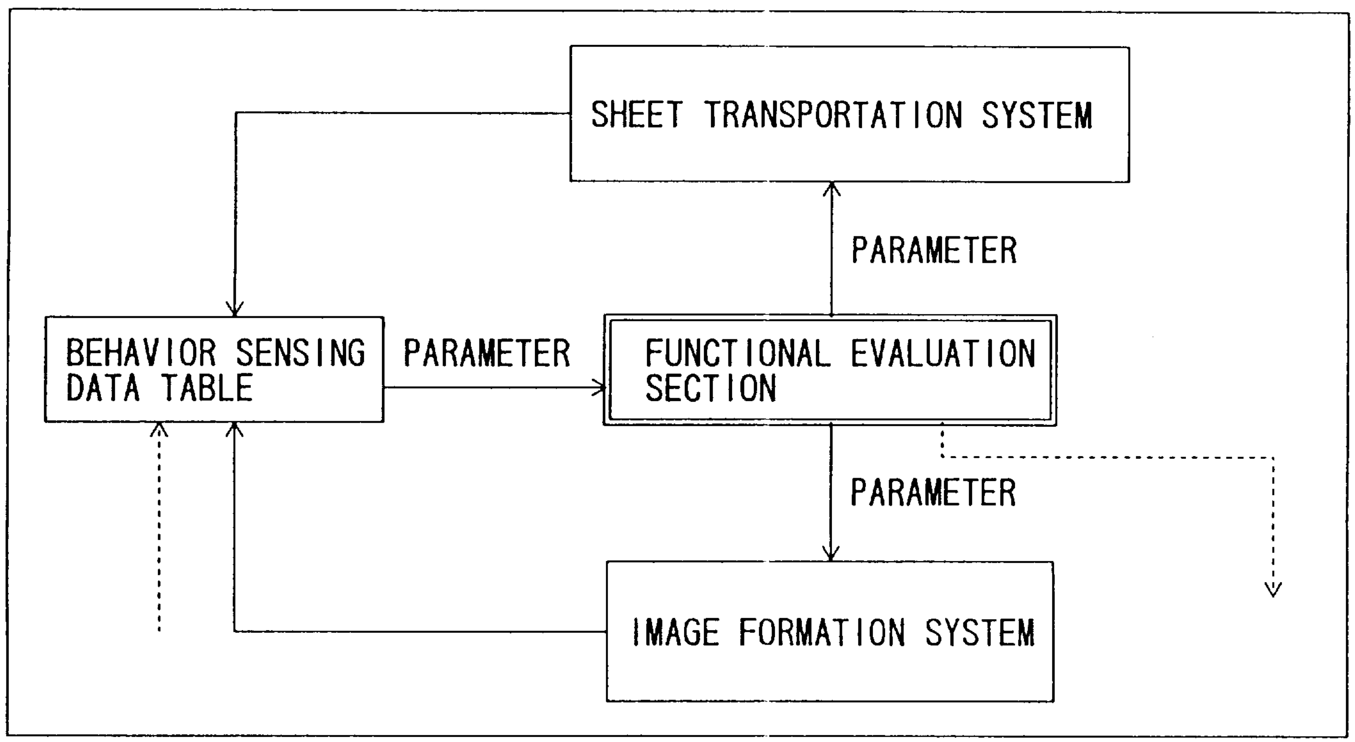

SHEET TRANSPORTATION SYSTEM
PARAMETER
BEHAVIOR SENSING DATA TABLE
PARAMETER
FUNCTIONAL EVALUATION SECTION
PARAMETER
IMAGE FORMATION SYSTEM

FIG. 3

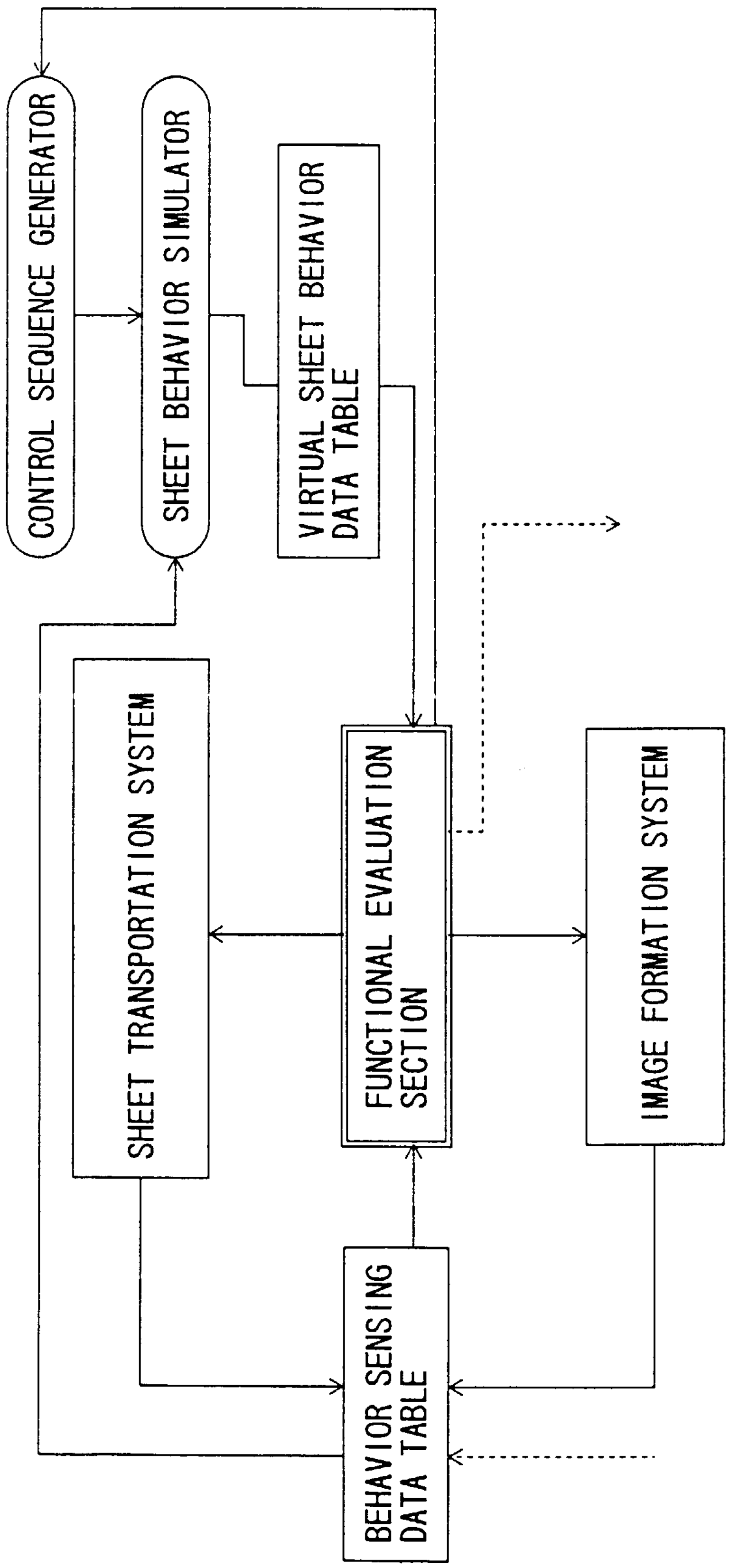

CONTROL SEQUENCE GENERATOR
SHEET BEHAVIOR SIMULATOR
VIRTUAL SHEET BEHAVIOR DATA TABLE
SHEET TRANSPORTATION SYSTEM
FUNCTIONAL EVALUATION SECTION
IMAGE FORMATION SYSTEM
BEHAVIOR SENSING DATA TABLE

FIG. 4

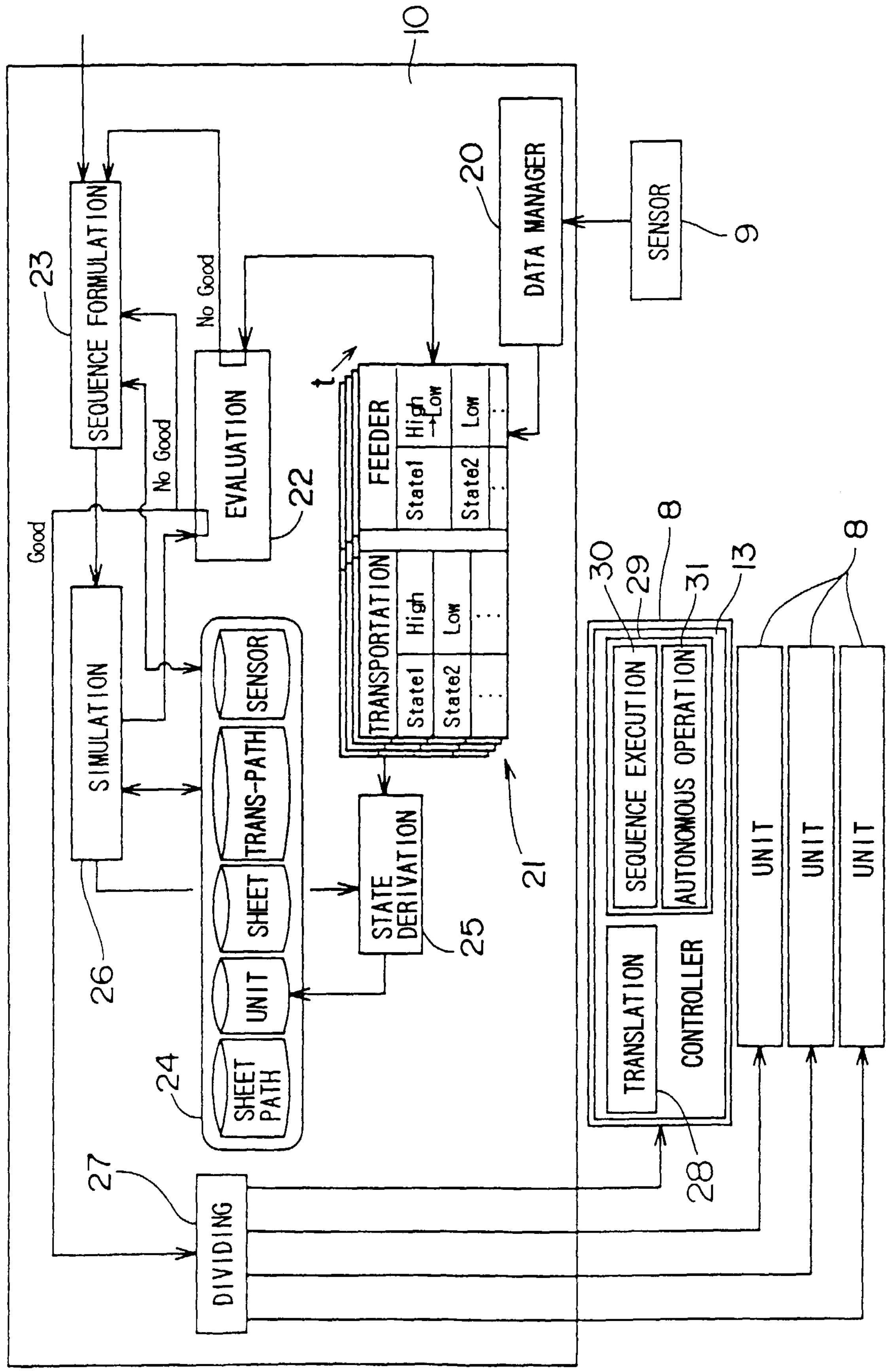
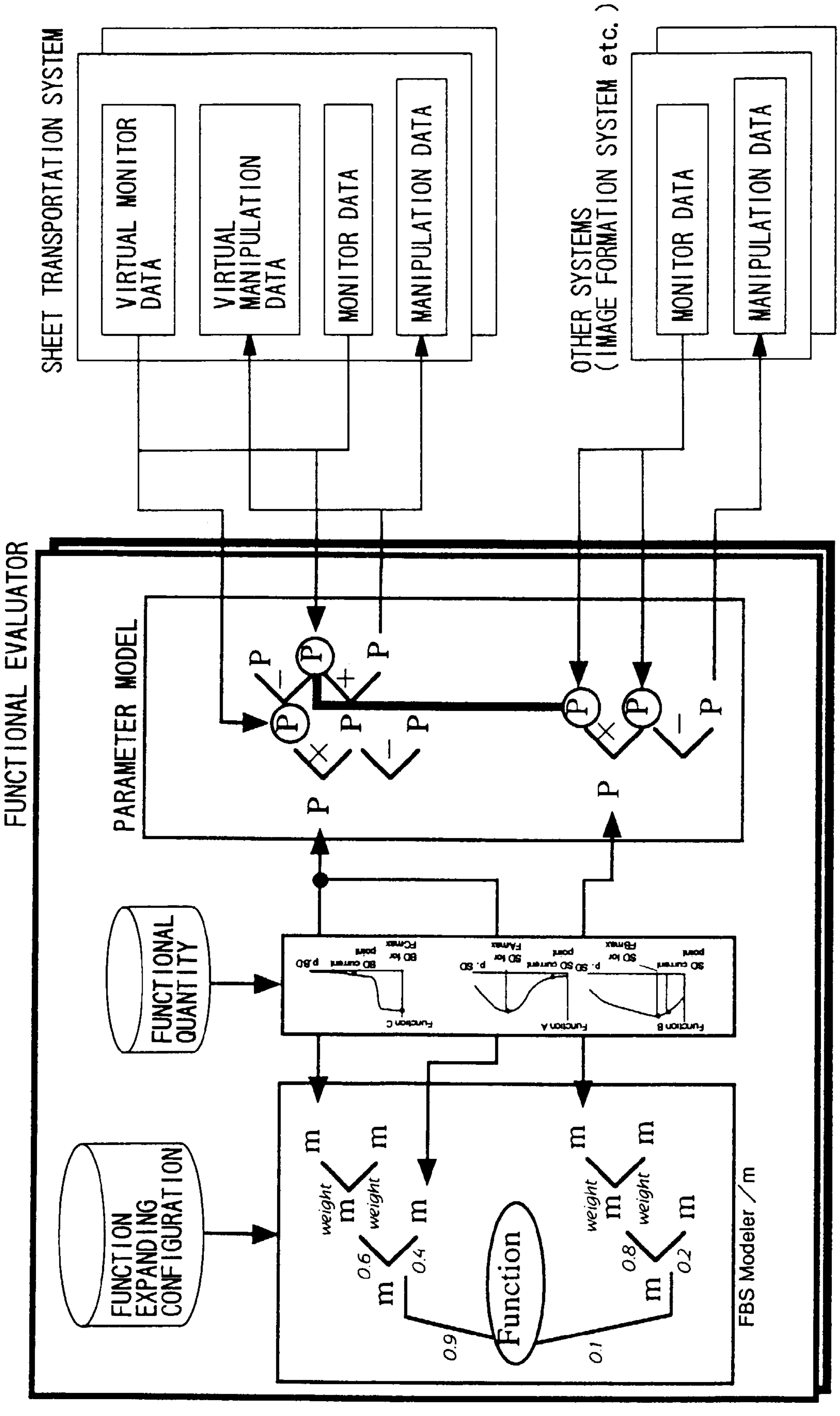

10
SEQUENCE FORMULATION
23
No Good
No Good
Good
EVALUATION
22
SIMULATION
26
SENSOR
TRANS-PATH
SHEET
UNIT
SHEET PATH
24
STATE DERIVATION
25
FEEDER
State1
High →Low
State2
Low
TRANSPORTATION
High
Low
t
21
DATA MANAGER
20
SENSOR
9
8
30
29
31
13
SEQUENCE EXECUTION
AUTONOMOUS OPERATION
TRANSLATION
CONTROLLER
28
UNIT
UNIT
UNIT
DIVIDING
27

FIG. 5


SHEET TRANSPORTATION SYSTEM
VIRTUAL MONITOR DATA
VIRTUAL MANIPULATION DATA
MONITOR DATA
MANIPULATION DATA
OTHER SYSTEMS (IMAGE FORMATION SYSTEM etc.)
MONITOR DATA
MANIPULATION DATA
FUNCTIONAL EVALUATOR
PARAMETER MODEL
FUNCTIONAL QUANTITY
FUNCTION EXPANDING CONFIGURATION
FBS Modeler / m
Function
weight
0.6
0.4
0.8
0.2
0.9
0.1

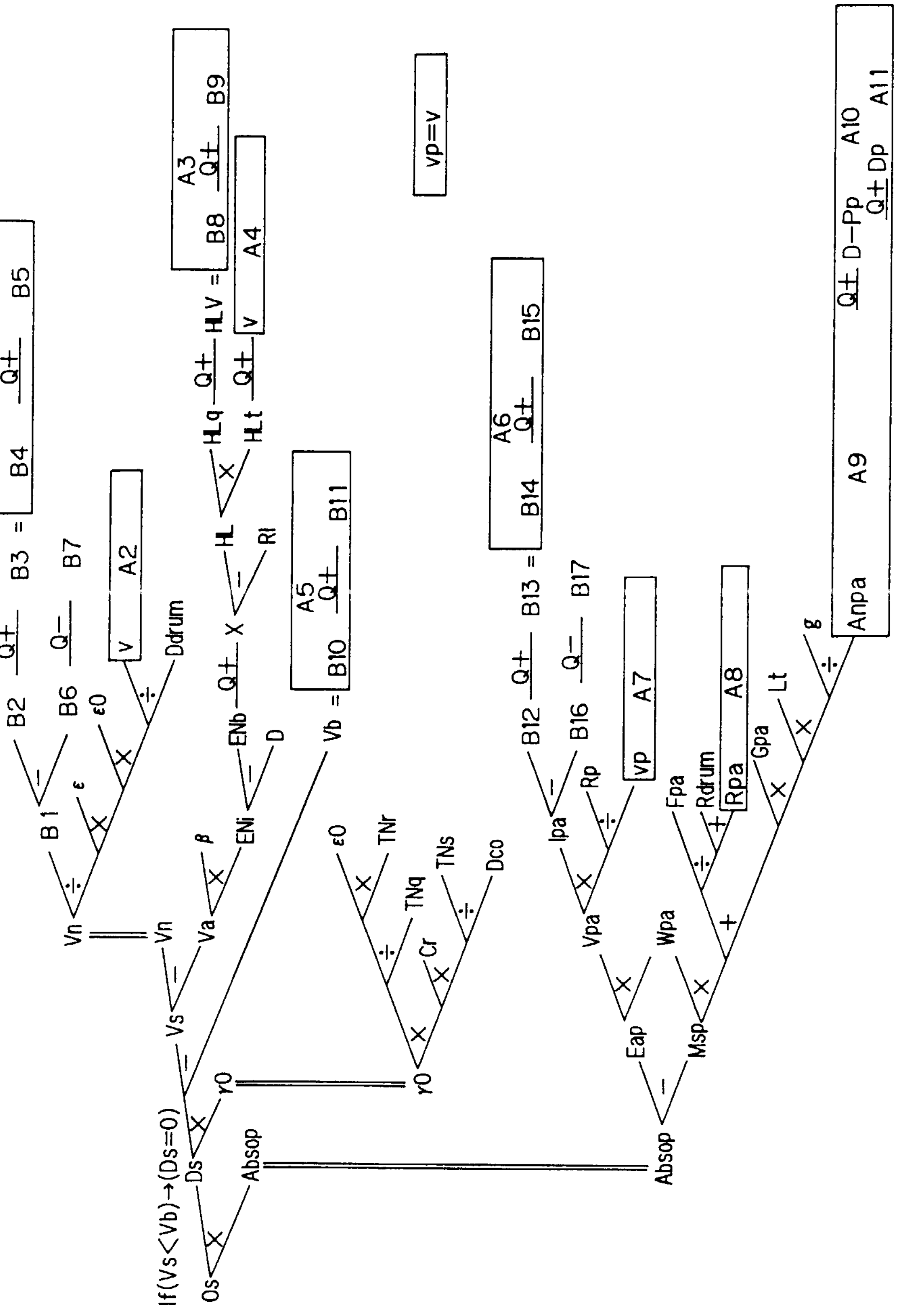


FIG. 6

FIG. 7

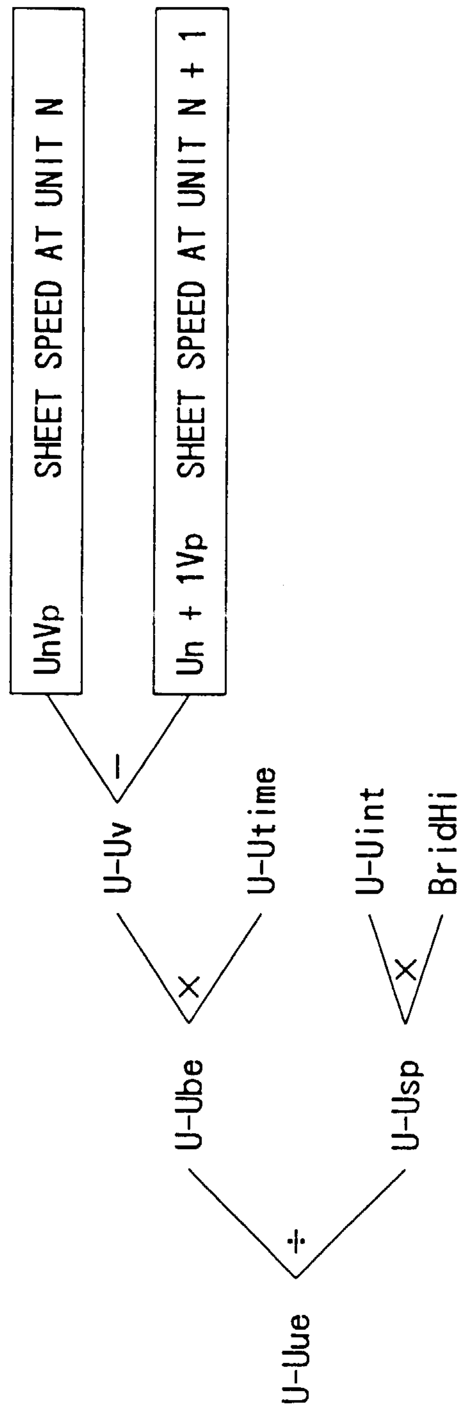
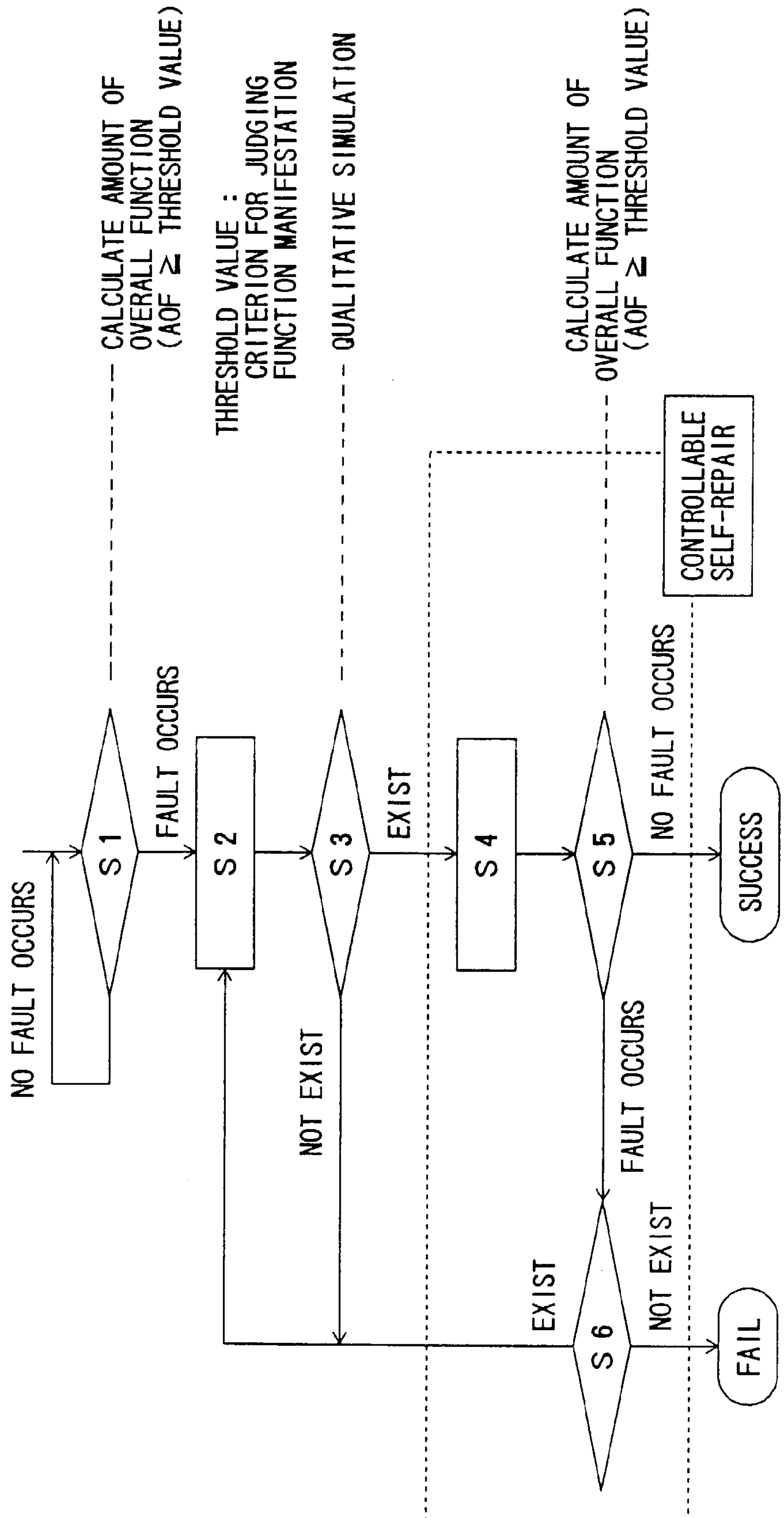
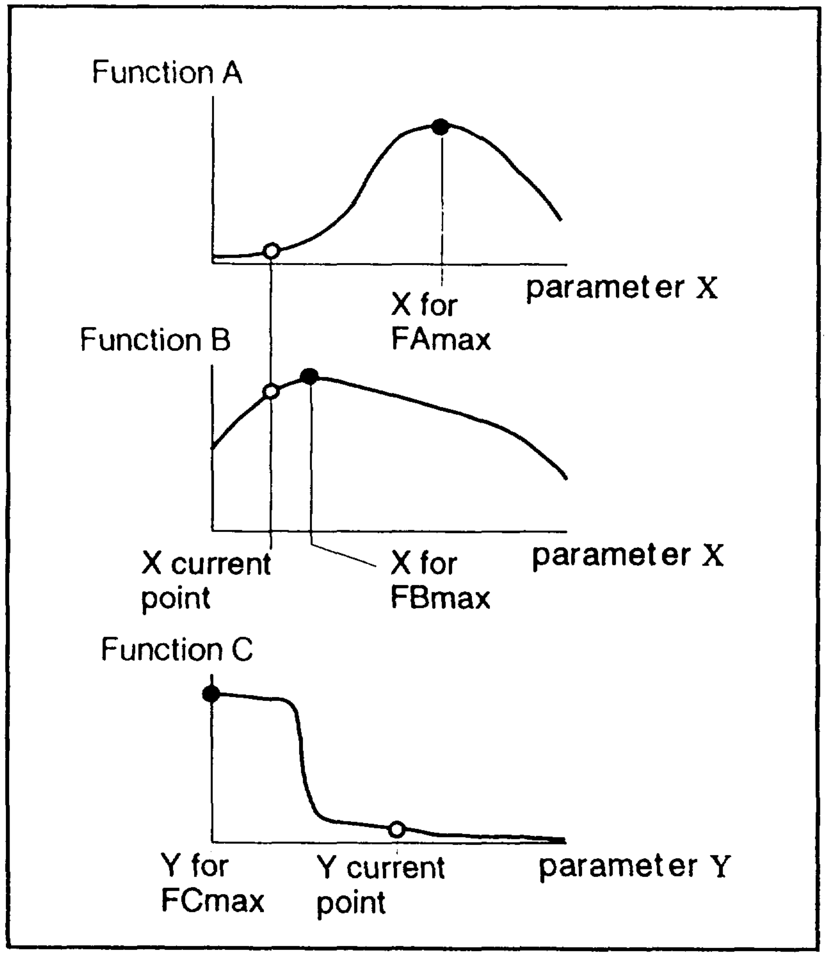

UnVp SHEET SPEED AT UNIT N
Un + 1Vp SHEET SPEED AT UNIT N + 1
−
U-Uv
U-Utime
×
U-Uint
BridHi
×
U-Ube
U-Usp
÷
U-Uue

FIG. 8

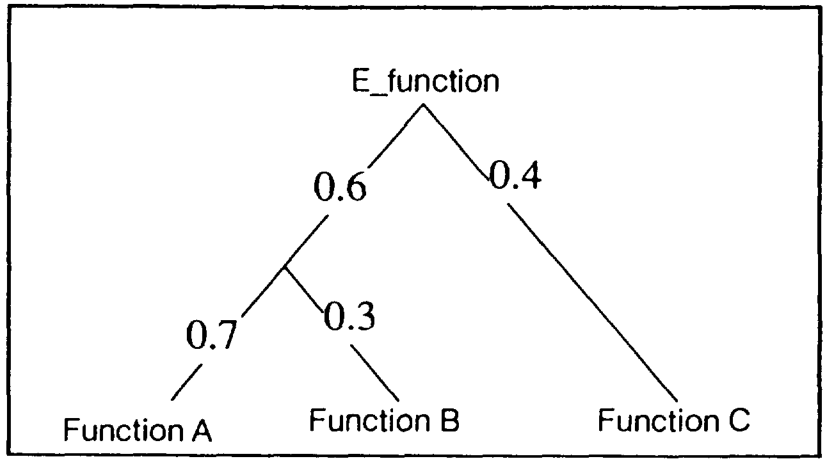

S1
S2
S3
S4
S5
S6
NO FAULT OCCURS
FAULT OCCURS
NOT EXIST
EXIST
NO FAULT OCCURS
FAULT OCCURS
EXIST
NOT EXIST
SUCCESS
FAIL
CALCULATE AMOUNT OF OVERALL FUNCTION (AOF ≧ THRESHOLD VALUE)
THRESHOLD VALUE : CRITERION FOR JUDGING FUNCTION MANIFESTATION
QUALITATIVE SIMULATION
CALCULATE AMOUNT OF OVERALL FUNCTION (AOF ≧ THRESHOLD VALUE)
CONTROLLABLE SELF-REPAIR

F I G. 9 A



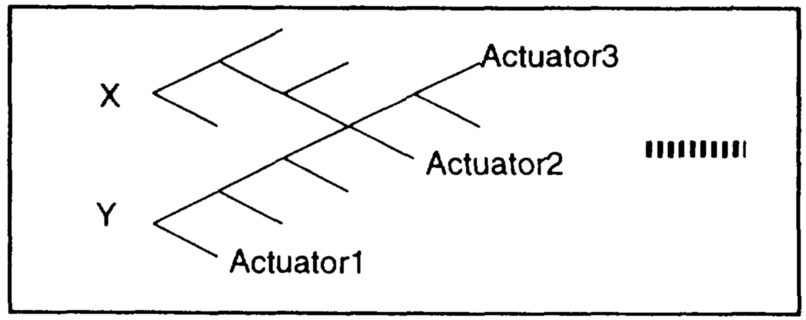
RELATIONSHIPS BETWEEN FUNCTIONS AND PARAMETERS FOR FUNCTIONAL EVALUATION (FUNCTIONAL QUANTITIES)

F I G. 9 B



FUNCTIONAL MODIFIER CONFIGURATION

F I G. 9 C



PARAMETER MODEL

FIG. 10A

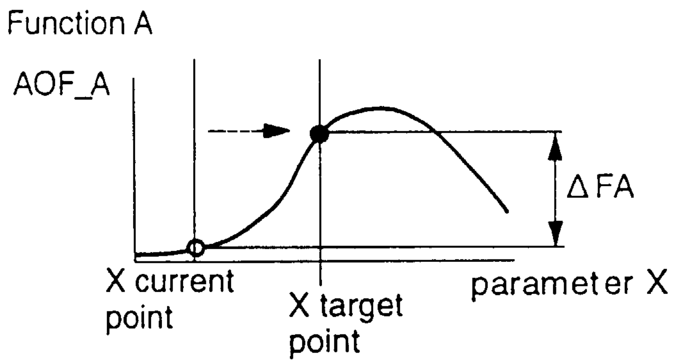


FIG. 10B

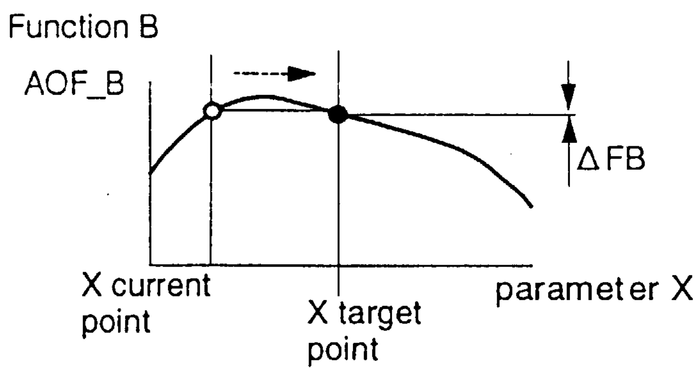
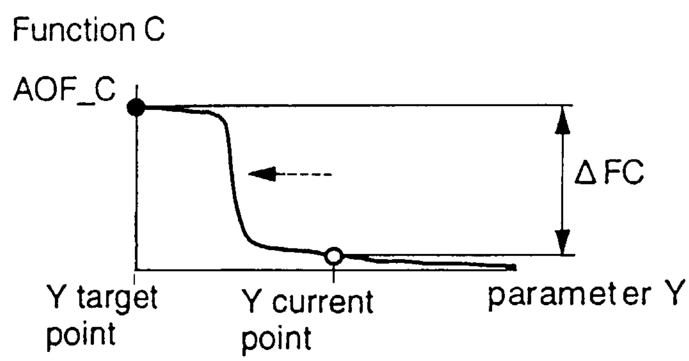


FIG. 10C



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 30 3424

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 5 467 355 A (MITA INDUSTRIAL CO.) 14 November 1995 * figures 7-9 *	1-6	G03G15/00
X	* abstract; figure 3 *	7-10	
X	US 5 515 503 A (SHIMOMURA YOSHIKI ET AL) 7 May 1996 * column 10, line 5 - column 11, line 3 *	1-6	
X	* figure 7 *	7	
X	US 5 239 547 A (TOMIYAMA TETSUO ET AL) 24 August 1993 * abstract *	1,2	
X	* figure 7 *	7	
X	US 5 166 934 A (TOMIYAMA TETSUO ET AL) 24 November 1992 * figure 2 *	1,2	
X	* figure 1 *	7	
X	US 5 463 545 A (UMEDA YASUSHI ET AL) 31 October 1995 * figure 21 *	1,2	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
X	* figure 27 *	3	G03G G06F
A	* the whole document *	4-10	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	29 September 1997	Kys, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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